MEDFORD CITYWIDE DRAINAGE MODELING

SOUTH MEDFORD FLOOD REDUCTION STRATEGIES

CITY OF MEDFORD, MASSACHUSETTS
06.26.2019

Contents

List of figures

List of tables

1. Introduction

The City of Medford has made significant strides in the path of climate change adaptation planning and has proactively developed initiatives to understand and evaluate the impacts to the City from climate change. The City recently published its Vulnerability Assessment Report[1] and is now working on developing a Climate Adaptation and Resiliency Plan. The adaptation plan will work to best address the vulnerabilities outlined in the assessment, and to explore strategies to increase the City's resilience to climate change. The City is an active member of the Metro Mayors Climate Preparedness Task Force[2], which is a coalition of 15 communities in Greater Boston to prepare the region for climate change and reduce greenhouse gas emissions as part of the coalition's Climate Preparedness Commitment[3]. The City is also one of the 10 Mystic River watershed communities that are part of the Resilient Mystic Collaborative[4], which has been founded by the Mystic River Watershed Association and the Consensus Building Institute to work on projects that can increase regional resilience.

In 2018 Kleinfelder developed a Citywide stormwater 2D flood model. Its purpose was to help the City gain a better understanding of which areas are more prone to future flood risks from storms that are likely to be more frequent and intense because of climate change. The findings from this Citywide model have been published as Appendix A to the City's Vulnerability Assessment Report. Subsequent to that, the City received two 2018 Municipal Vulnerability Preparedness Action Grants from the State to continue the work of climate preparedness. This report is the work of one of those grants, which allowed Kleinfelder to further refine the model for South Medford and to explore infrastructure and policy recommendations to mitigate future flooding impacts.

South Medford area is a low-lying, densely populated urban environment that is vulnerable to flood impacts from current storms. Climate change can cause more frequent and higher intensity rainstorms that exacerbate the flooding impacts. The subsequent sections of this report are structured to discuss the following aspects:

- Model refinement in South Medford to gain a more accurate understanding of the stormwater flood risks
- Neighborhood-wide flood reduction strategies, including stormwater policy recommendations
- Site-specific flood reduction strategies, including both gray and green infrastructure to mitigate flood impacts
- Summary of results and next steps

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[1] Medford Climate Change Vulnerability Assessment, January 2019
https://drive.google.com/file/d/1DvxUiXpGnp8soxA3njZUgCSMBcWki_fm/view

[2] https://www.mapc.org/our-work/expertise/climate/mmc/

[3] Metropolitan Boston Climate Preparedness Commitment, May 2015
http://www.mapc.org/wp-content/uploads/2017/09/FINAL-Metropolitan-Mayors-Climate-Mitigation-Commitment.pdf

[4] https://mysticriver.org/resilient-mystic-collaborative

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1.1. Citywide Model Review

The Citywide hydrologic/hydraulic stormwater model was developed in PCSWMM to evaluate potential future flood impacts within the City's boundary. The citywide model serves as a foundation to analyze stormwater system performance under existing conditions and to evaluate system performance under future climate both without and with potential improvements related to stormwater infrastructure and policy implementation.

The citywide model includes the entire Mystic River Watershed starting upstream from the Amelia Earhart Dam (AED). Upstream tributary areas are bounded by Reading, MA from the North, Malden, MA from the east, Arlington from the west, and Somerville from the south.

A simplified network of the City's drainage system was represented mostly by drain pipes larger than or equal to 18-inch in diameter (Figure 1). The citywide model included 705 catchments connected to the simplified network which simulated the hydrology in the watershed. The model was used to conduct simulations for the 10-year 24-hour and 100-year 24-hour design storms for present, 2030 and 2070 planning horizons. Details of the citywide model development and scenario results are summarized in the technical memo by Kleinfelder as Appendix A to the City's Vulnerability Assessment Report[5].

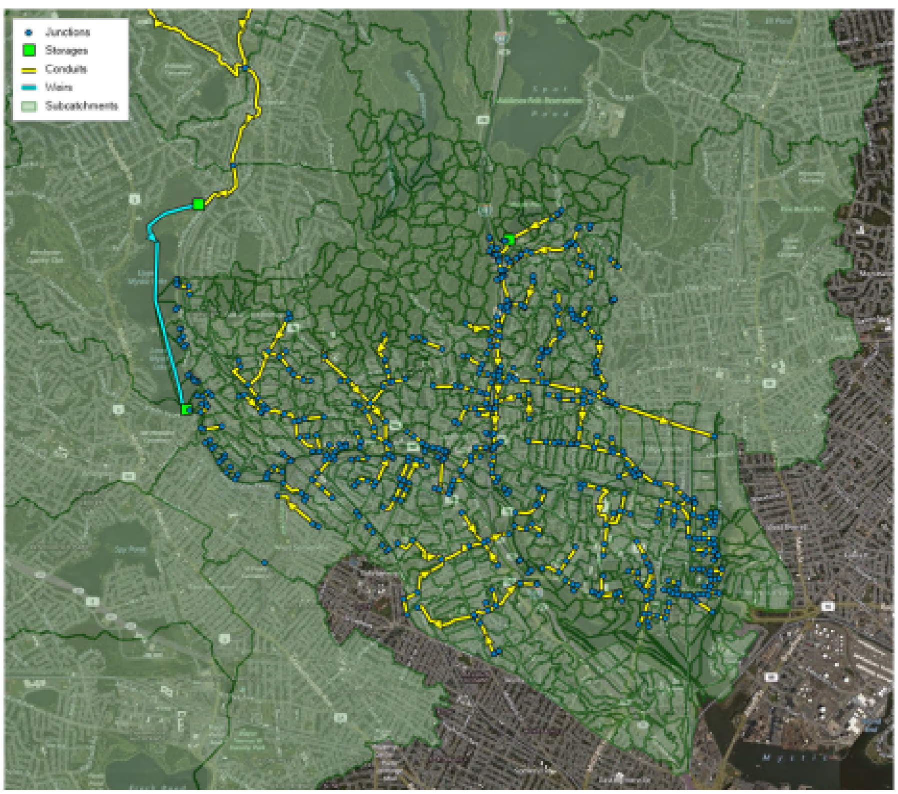


Figure 1 – Citywide model overview in PCSWMM with simplified drainage network

[5] Appendix A to Medford Climate Change Vulnerability Assessment, January 2019
https://drive.google.com/file/d/1DvxUiXpGnp8soxA3njZUgCSMBcWki_fm/view

1.2. Three Impact Areas – South Medford pilot

From the citywide model, three main areas within the City were identified as potential pilot areas to evaluate flood mitigation strategies, highlighted below in Figure 2.

Figure 2 – Three potential pilot areas in Medford to evaluate flood mitigation strategies

West Medford – The area is directly downstream of the Middlesex Fells reservations and the Winchester reservoirs. Flow releases from the reservoirs, managed by the City of Winchester, can have detrimental flood impacts to the West Medford area if timed coincidentally during the peak of a rainstorm. Further analyses are warranted to study the interactions of the drainage system and the upstream tributary flows from the reservation and the reservoirs.

Wellington – Route 16 circle and the Wellington MBTA station are both transportation arteries connecting vehicles and passengers to and from Boston. Flood impacts even at small scales can cause great disturbance to travelers and can have a domino effect to detour traffic patterns in surrounding towns and communities.

South Medford – Stormwater flows in this area concentrate quickly from small hills from Somerville. The concentrated stormwater flows can pond in low-lying areas in various locations within South Medford, causing access problems to major streets. Residents can lose access to critical infrastructure such as the

Kidney Dialysis center on Mystic Avenue, or flooding can impact operations at the DPW and Police Headquarters on Main Street. The mix of commercial and mostly high to medium density residential with limited open space available creates a highly urbanized environment that would be challenging to accommodate new infrastructure to enhance the drainage system. This report will focus on the South Medford area as a pilot to evaluate the effectiveness of flood mitigation strategies that combine gray and green infrastructure to mitigate flooding under present and future scenarios.

2. Hydrologic and Hydraulic (H&H) Model Refinement

As part of this study, various updates were completed to the Citywide hydrologic/hydraulic model and specifically to the South Medford area to improve model calibration, which will allow better representation of the drainage system's performance. Calibration was conducted to match model results against observed data from rainstorms in March and April 2018. The following section details the model refinements that were completed to produce updated flood results for the South Medford area.

2.1. Additional Rain Gages

Additional rain gages were added as part of model calibration. Previously in the Citywide model, one USGS rain gage on the Aberjona River in Woburn was used for all catchments. In the updated model for this study, four additional rain gages were added to catchments at Oak Grove, Edgeworth, Tufts, and Fresh Pond, to simulate the heterogenous rain fall distributions over the Boston Metro area. Figure 3 below shows an overview of the rain gage locations and the associated catchments in the stormwater model.

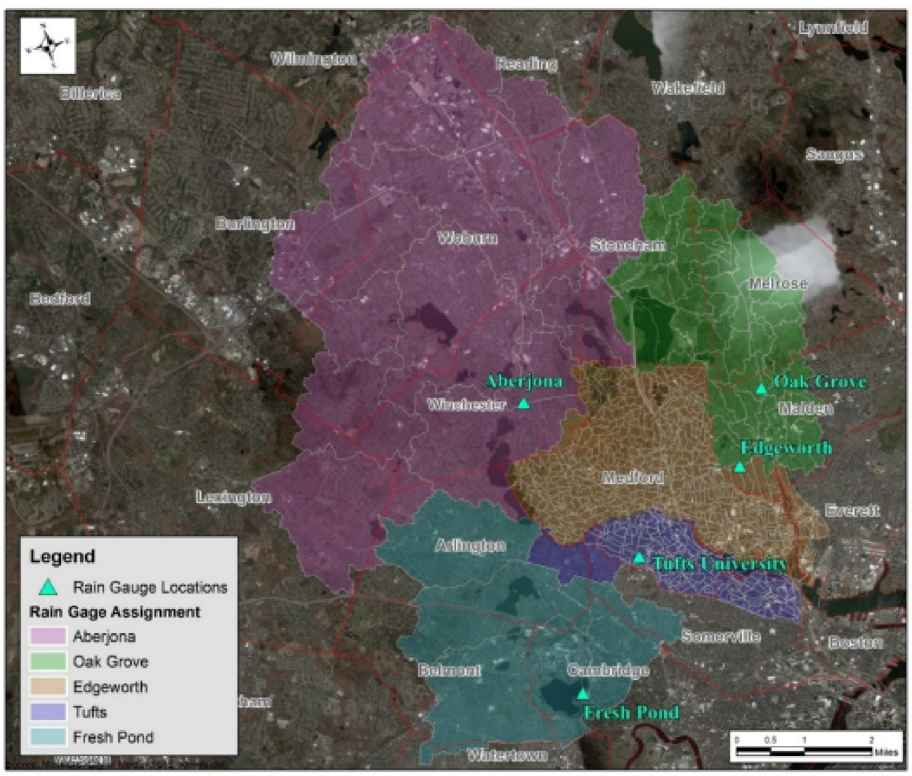


Figure 3 – Rain gage locations and corresponding catchments and respective rain gages in the stormwater model

2.2. Catchment Delineation Improvement

In the previous Citywide model, catchments upstream of the Malden River were coarsely delineated and simplified since the Malden River is not a dominant flow contributor to the Mystic River watershed. In the updated model for this study, catchment delineation in the Malden and Oak Grove areas were further refined to better represent surface runoffs routed from the added rain gage at Oak Grove.

2.3. Bridge Crossing Restrictions

Along the Mystic River, between the Lower Mystic Lake and the Amelia Earhart Dam, there are a total of twelve bridge crossings. Some of these bridge crossings create narrower cross section geometries or have multiple bridge columns that can restrict the river flows. Using information provided from a combination of elevation data from LiDAR Digital Elevation Model (DEMs) using the MassGIS 2013-2014 Sandy LiDAR dataset, satellite images and GIS data, the hydraulics of the bridge crossing were incorporated in the updated model. Figure 4 shows the cross section of the Craddock Dam and the Main Street bridge crossing before and after reconstruction. Figure 5 shows how these construction changes to the bridge crossings were incorporated in the model using 1D conduits.

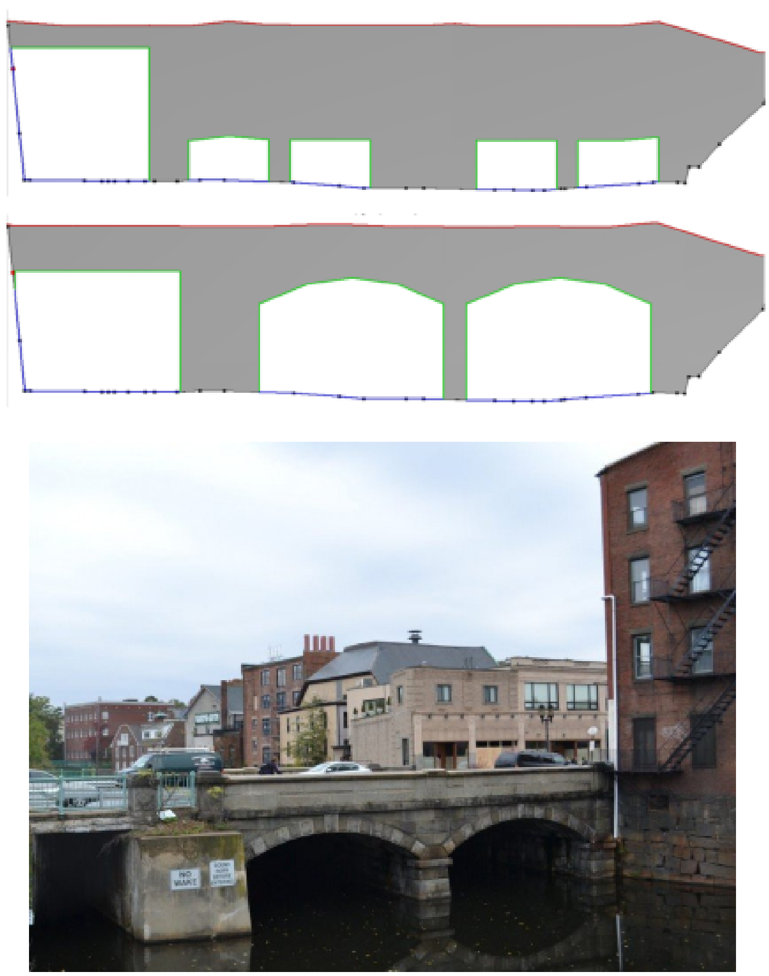


Figure 4– Pre- and Post-reconstruction cross sections of the Cradock Dam (top); and Photo of reconstructed bridge Crossing (bottom)

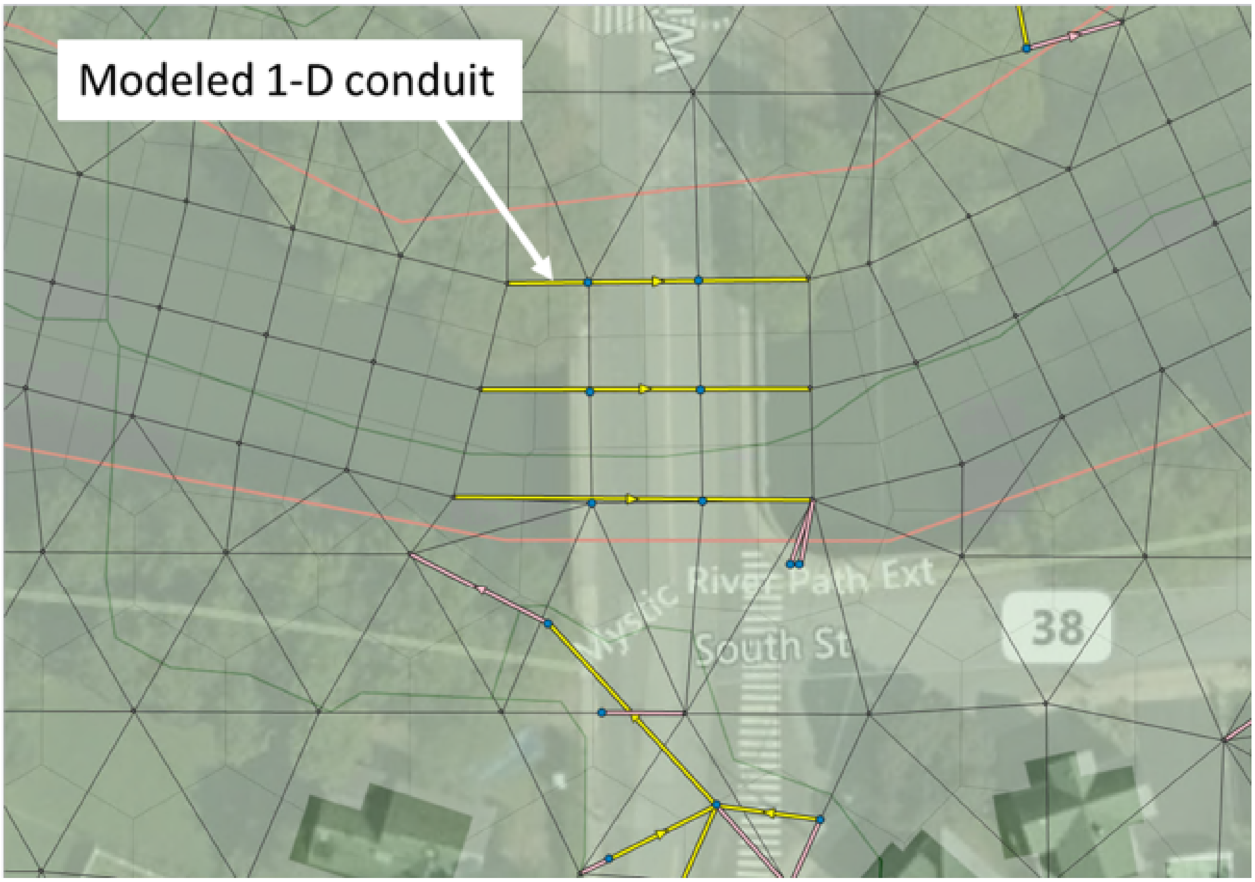


Figure 5 – Craddock's Dam bridge restriction represented in PCSWMM model

2.4. 1D/2D Model Refinement

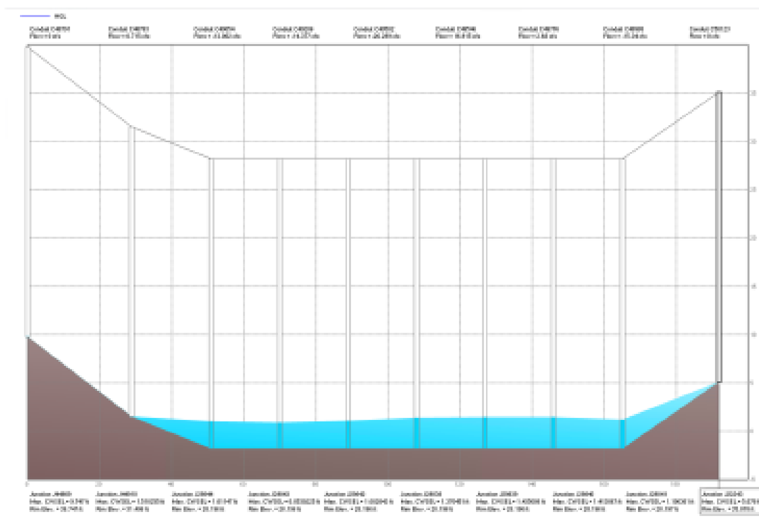
Within the South Medford area, the model was updated to include all the known drainage pipes, manholes and catch basins based on information provided by the City's GIS. These additional pipes, manholes and catch basins in the model help to better simulate hydraulic performances at a smaller, local street scale. To complement the updated 1D model network, the 2D surface mesh used to visualize surface flooding was also refined to more accurately simulate surface flooding at smaller and local street scales.

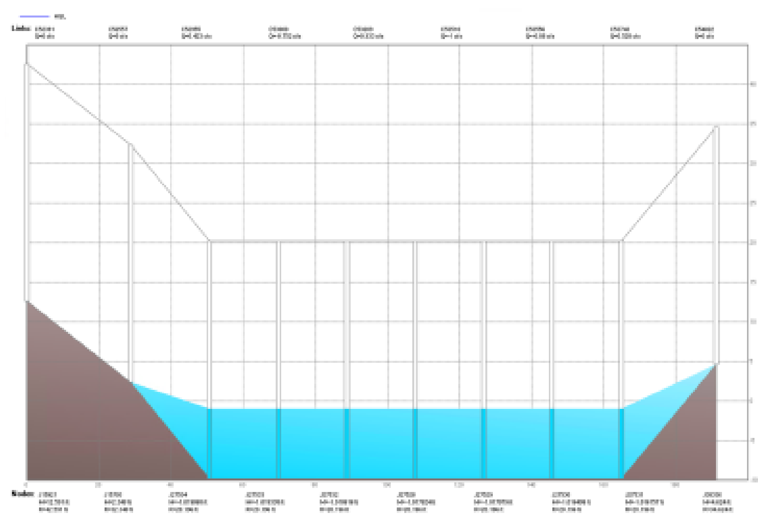
In the 2018 Citywide model, the stormwater system in the South Medford area included approximately 36,400 linear feet of drainage pipes connected with 88 junctions (manholes, catch basins) as illustrated in top panel of Figure 6. In the updated model as part of this study, the stormwater system in South Medford includes 143,000 linear feet of pipes connected to 2002 junctions (manholes, catch basins) as illustrated in bottom panel of Figure 6. The average cell size of the 2D mesh in South Medford is reduced from 5,762 square feet in the Citywide model to 1,980 square feet in this study, increasing the number of 2D mesh cells in South Medford from 6,398 cells to 17,125 cells.

Figure 6 – 1D-network comparison between Citywide model (top) and updated South Medford model (bottom)

2.5. Updated Bathymetry

For the Citywide model, a DEM was used to generate a 2D mesh surface. This DEM included a simplified representation of the river bathymetry as the approximate low water elevation in the Mystic River (-1.804 ft-NAVD88). For the high-level planning completed in the previous phase, this provided an adequate approximation of the river bathymetry. However, by not representing the full depth of the Mystic River, the Citywide model overestimated overland flooding along the riverbank particularly in the narrower sections of the Mystic River upstream of the Main Street bridge crossing. The bathymetry used in the Citywide model was replaced with updated bathymetry data obtained from the NOAA[6] and verified by MWRA sampling data for the Mystic River[7]. Figure 7 – Modeled shows an example cross section of the river bathymetry from the Citywide model compared to the updated South Medford model.





[6] https://www.charts.noaa.gov/OnLineViewer/13272.shtml

[7] http://www.mwra.state.ma.us/harbor/html/mr_wq.htm

Figure 7 – Modeled Mystic River cross section from Citywide model (top); and South Medford model (bottom)

Figure 8 shows a revised calibration plot comparing observed and modeled river water depth at the USGS gage for the Mystic River located at the High Street bridge crossing. The comparison shows that there is a good match between the simulated river depth and the observed river depth based on a calibration rainfall event in Spring 2018. The mismatching peaks (i.e. around April 18th), can be explained by the simplified rainfall input and pump operations at the AED, and could be improved in the future should the City receive additional information regarding operations at the AED.

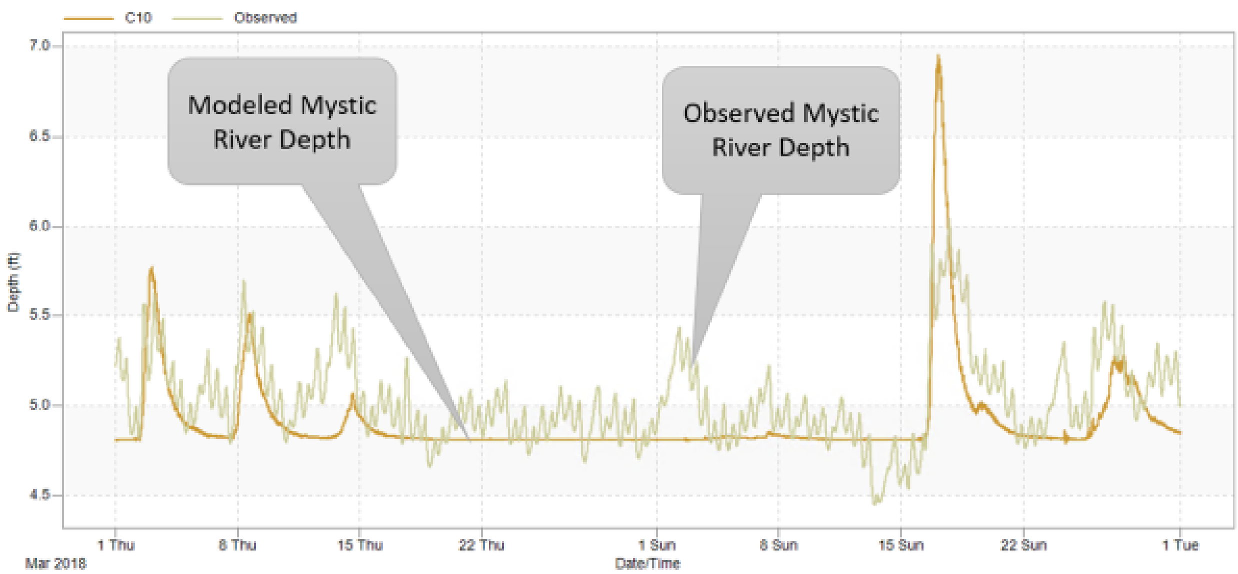


Figure 8 – Mystic River depth calibration timeseries from March 2018 to April 2018

2.6. Updated 10-year and 100-year flood results for South Medford

The updated South Medford model was used to simulate six storm scenarios, which include the present, 2030 and 2070 10-year and 100-year 24-hour design storms. The results in terms of peak flood volume, percent area flooded (of the total 956 acres in South Medford), and percent of properties (of the total 4,131 properties in South Medford) affected by flooding for each of the six scenarios are summarized in Table 1. Figure 9 through Figure 14 illustrate the flood maps for each of the six scenarios.

Table 1 – Summary of flood statistics for design storm scenarios

Parameter	10-Year, Present Conditions	10-Year, 2030 Conditions	10-Year, 2070 Conditions	100-Year, Present Conditions	100-Year, 2030 Conditions	100-Year, 2070 Conditions
Flood Volume (MG)	12.2	13.8	15.6	31.8	33.0	41.4
Percent South Medford Area Flooded (%)	6%	7%	9%	14%	15%	17%
Percent South Medford Parcels Flooded (%)	16%	18%	20%	28%	30%	31%

In general, the refinements made to the 1D/2D model allow runoff and overland flow to drain towards low-lying areas that were not identified in the previous model. For example, the MBTA commuter rail tracks with the coarser resolution in the Citywide model did not adequately represent the depression along the rail tracks near Boston Avenue. In the updated model, this depression is simulated better by the finer 2D mesh and as a result, the overland flood waters are routed onto the rail tracks and flow along Boston Avenue following the slope of the terrain.

The updated model can also capture the change in street grade and determine whether localized flood problems are contained within the public right of way, or breaching into nearby parcel areas, and therefore provide more accurate flood results at the street scale.

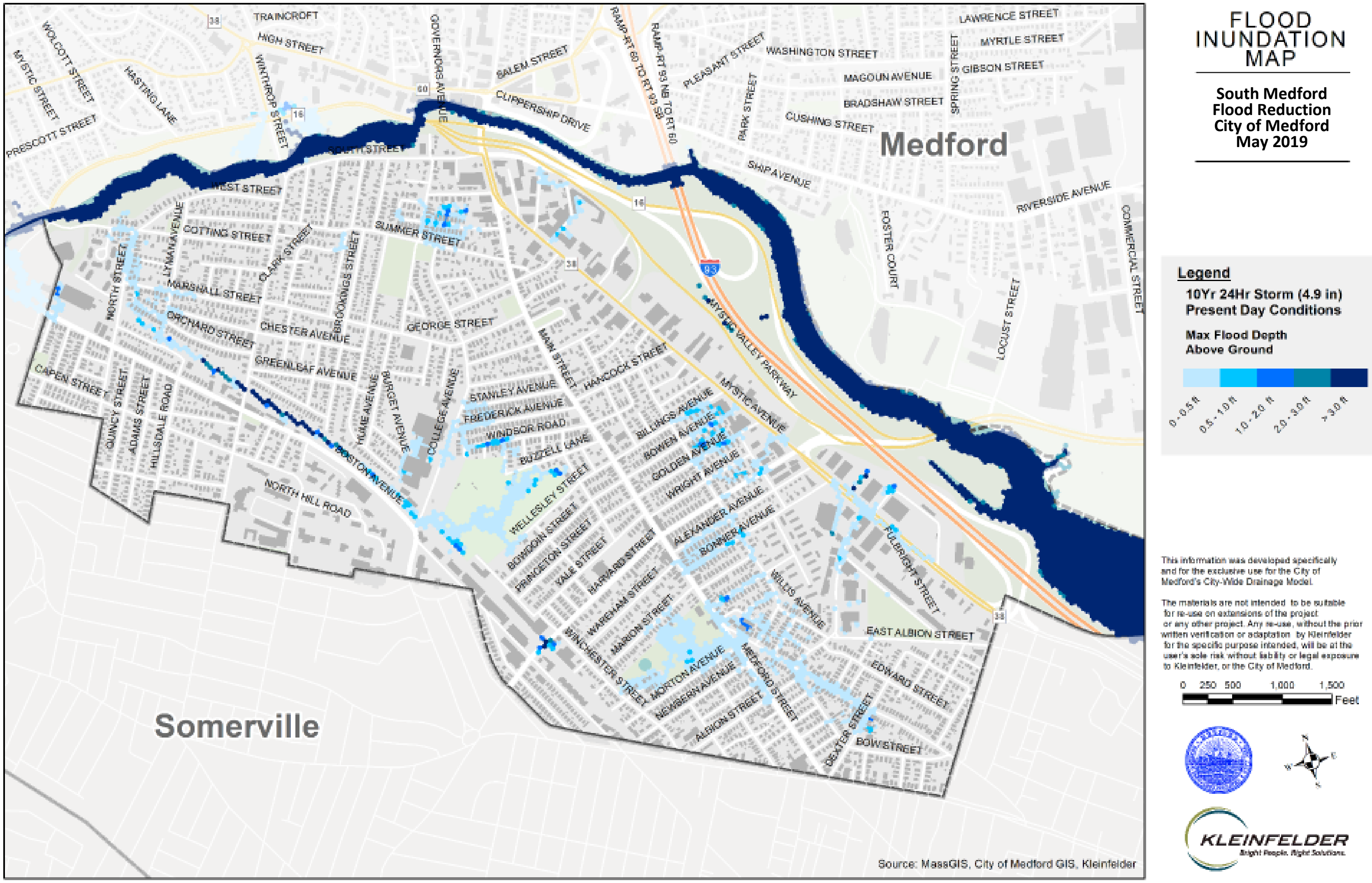


Figure 9 – Present 10-year 24-hour storm flooding

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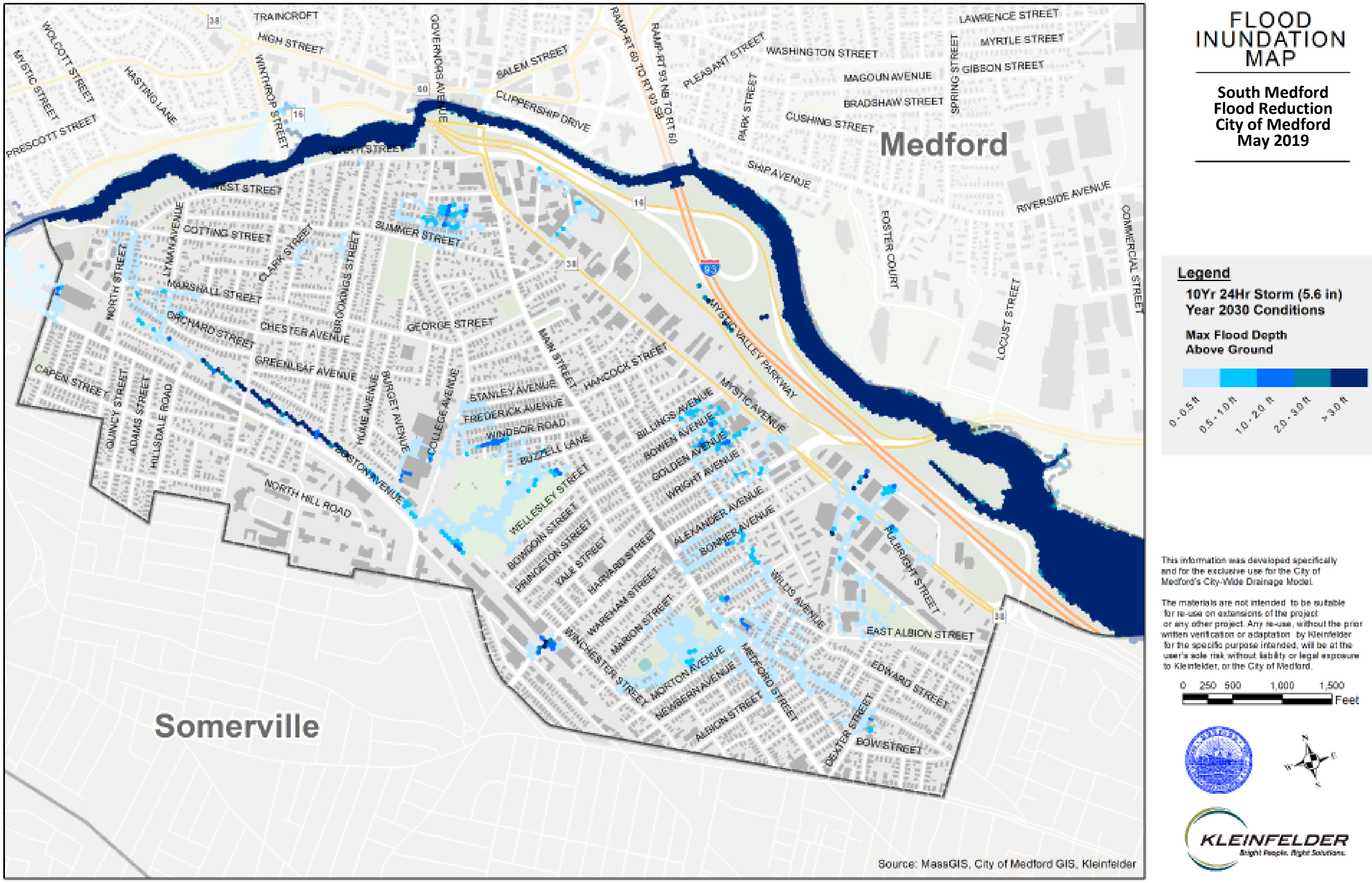


Figure 10 - 2030 10-year 24-hour storm flooding

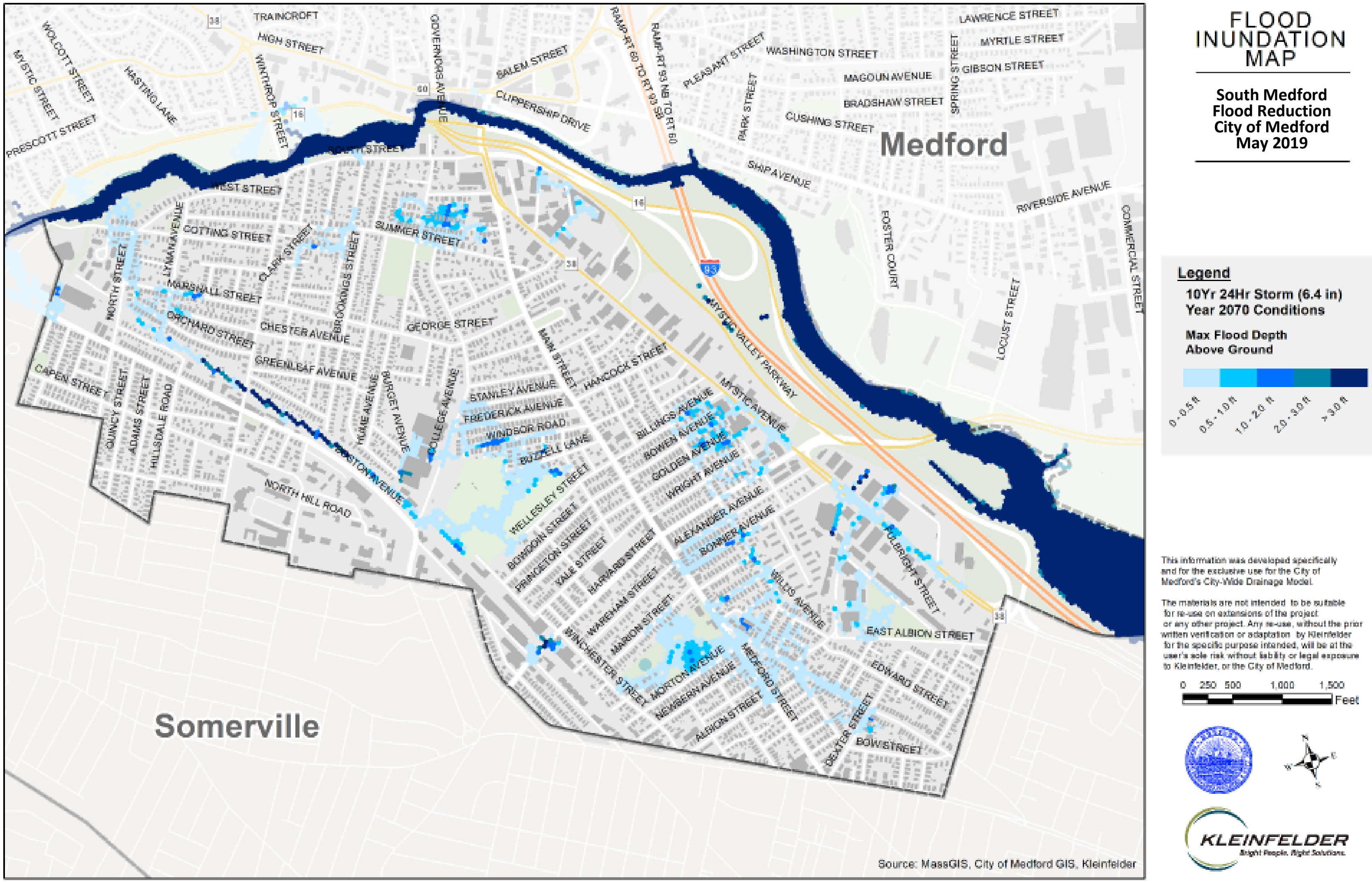


Figure 11 - 2070 10-year 24-hour storm

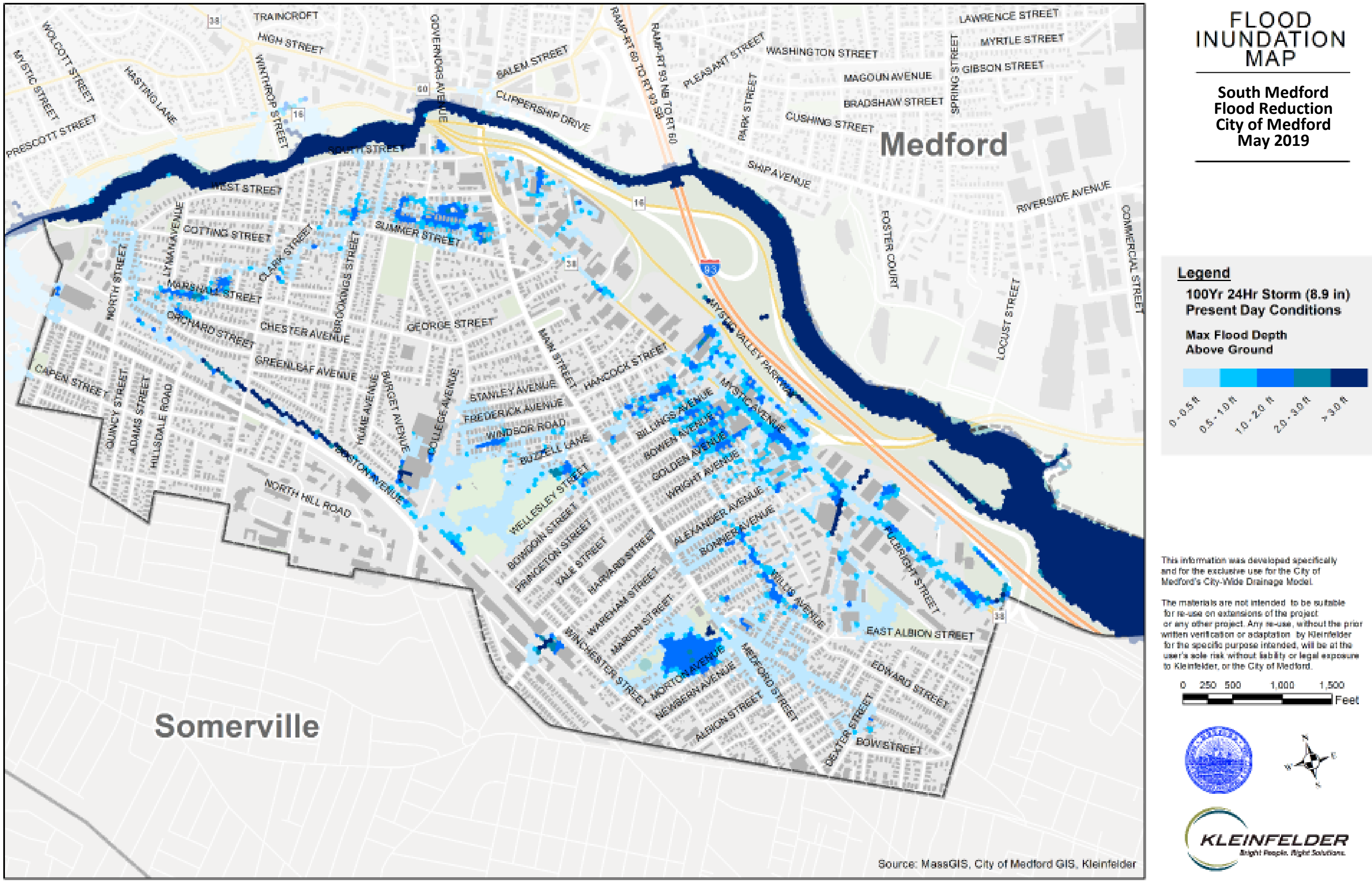


Figure 12 - Present 100-year 24-hour storm

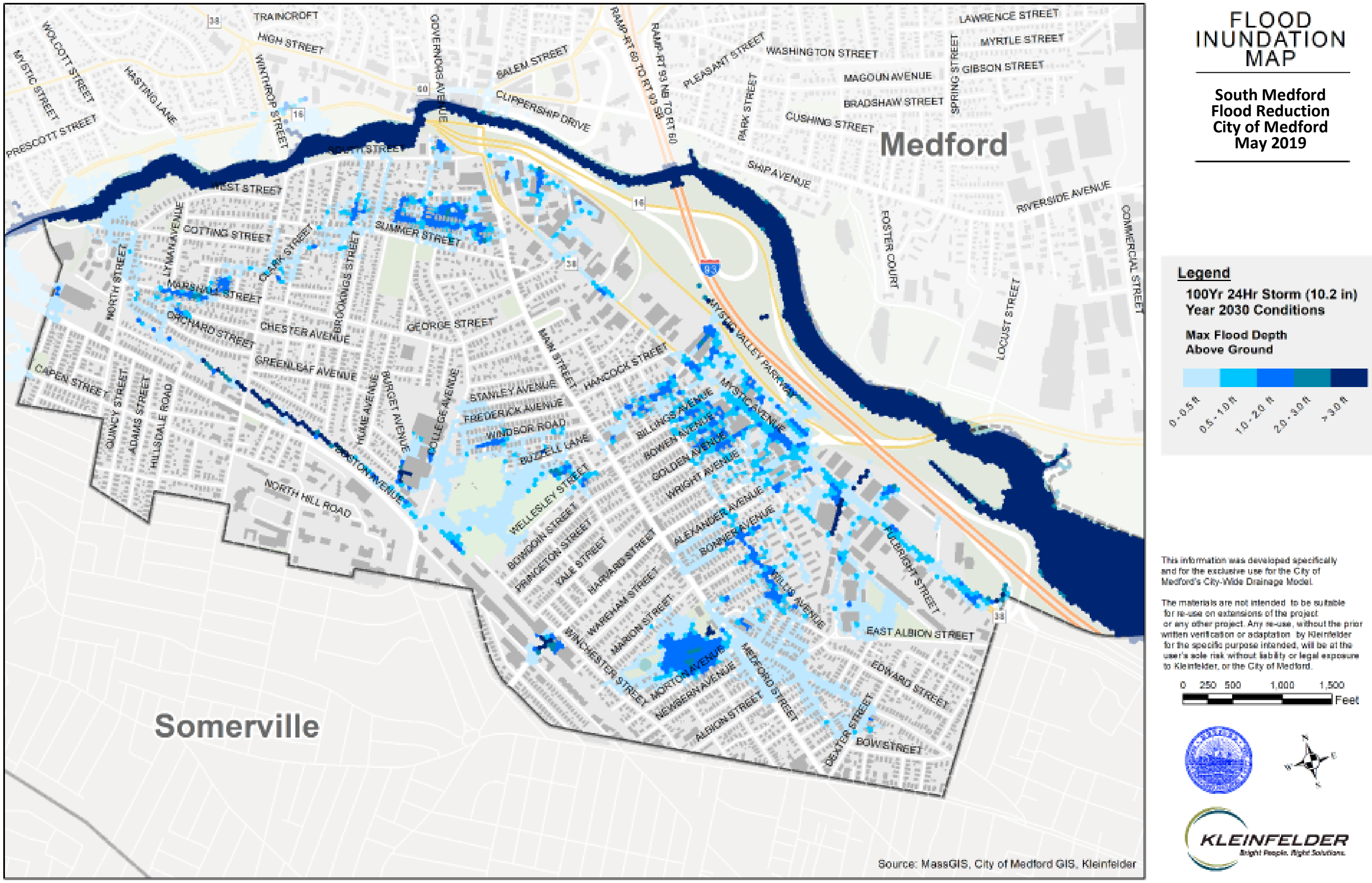


Figure 13 - 2030 100-year 24-hour storm

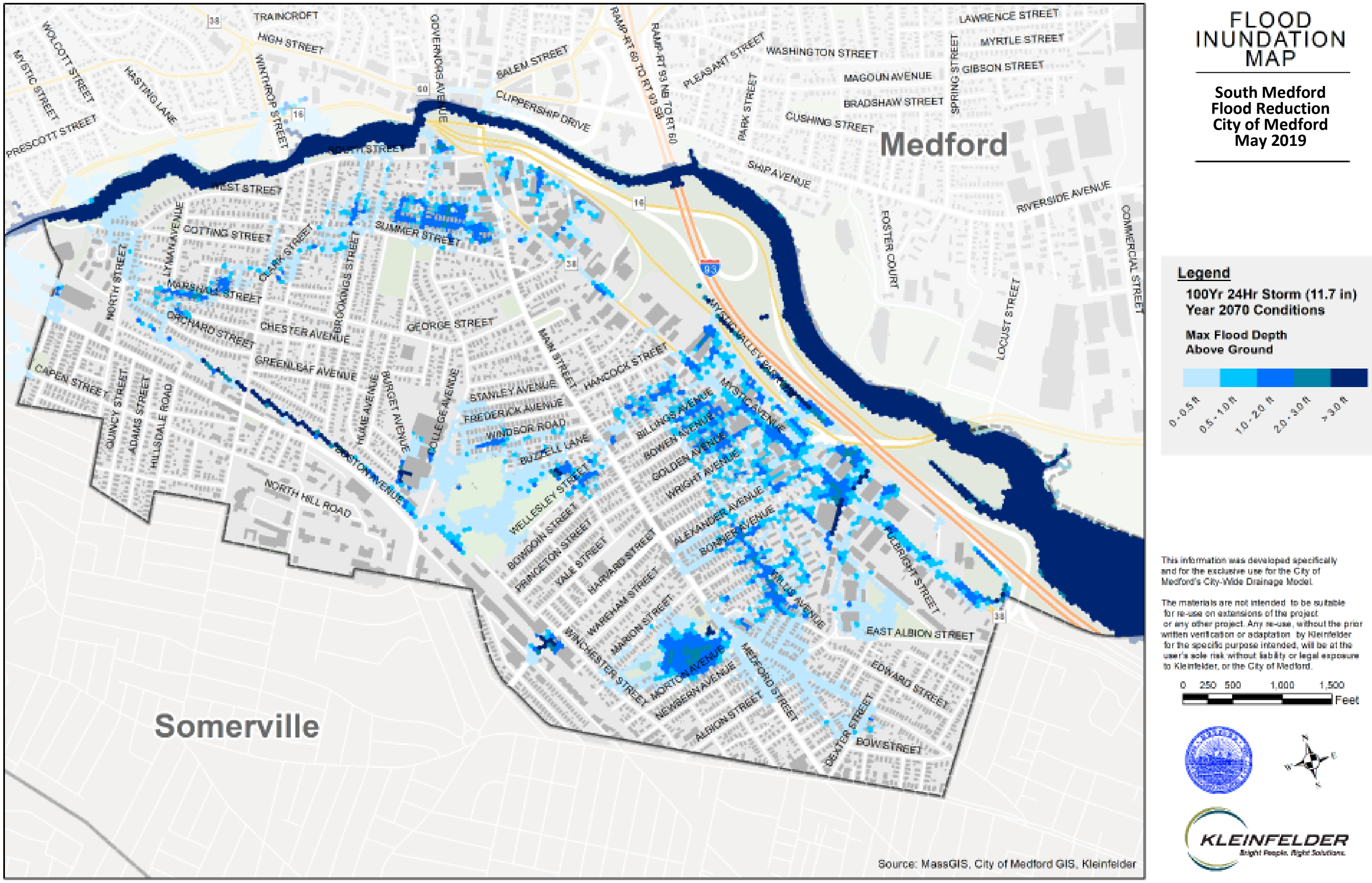


Figure 14 - 2070 100-year 24-hour storm

3. Additional Project Included in Model – Tufts University Alumni Fields

Tufts University recently completed a project near the university-owned Alumni Fields on College Avenue. The project involves rerouting stormwater flows from Sunset Avenue to an infiltration and detention tank in the southwest corner of the Alumni Fields (Figure 15). When the tank is at capacity, flows will be discharged to an outfall control structure on Wellesley Street connecting to existing drainage pipes. This project will help to lengthen the time of concentration of the stormwater flows contributed from drainage pipes on Sunset Avenue. The infiltration tank has around 1 million gallons (MG) of storage capacity and can help to attenuate stormwater peak flows to restore downstream conveyance capacity in the Wellesley Street / Main Street intersection.

Based on as-built construction plans, the rerouting and implementation of the Alumni Fields Tank modifications are included in the updated model. Figure 15 below shows an overview of the site improvements and Figure 16 shows the expected flood mitigation benefits to the College Avenue area by comparing modeled flood results with the infiltration tank (blue) and without the tank (red). The installation of the Alumni Fields Tank is expected to provide localized flood mitigation benefits in the area of College Avenue particularly for the university owned property on 161 College Avenue. This new tank was included in the modeled scenarios for the site-specific gray and green flood mitigation strategies discussed in Section 4 of this report.

Figure 15 – Tufts University Alumni Fields stormwater improvements

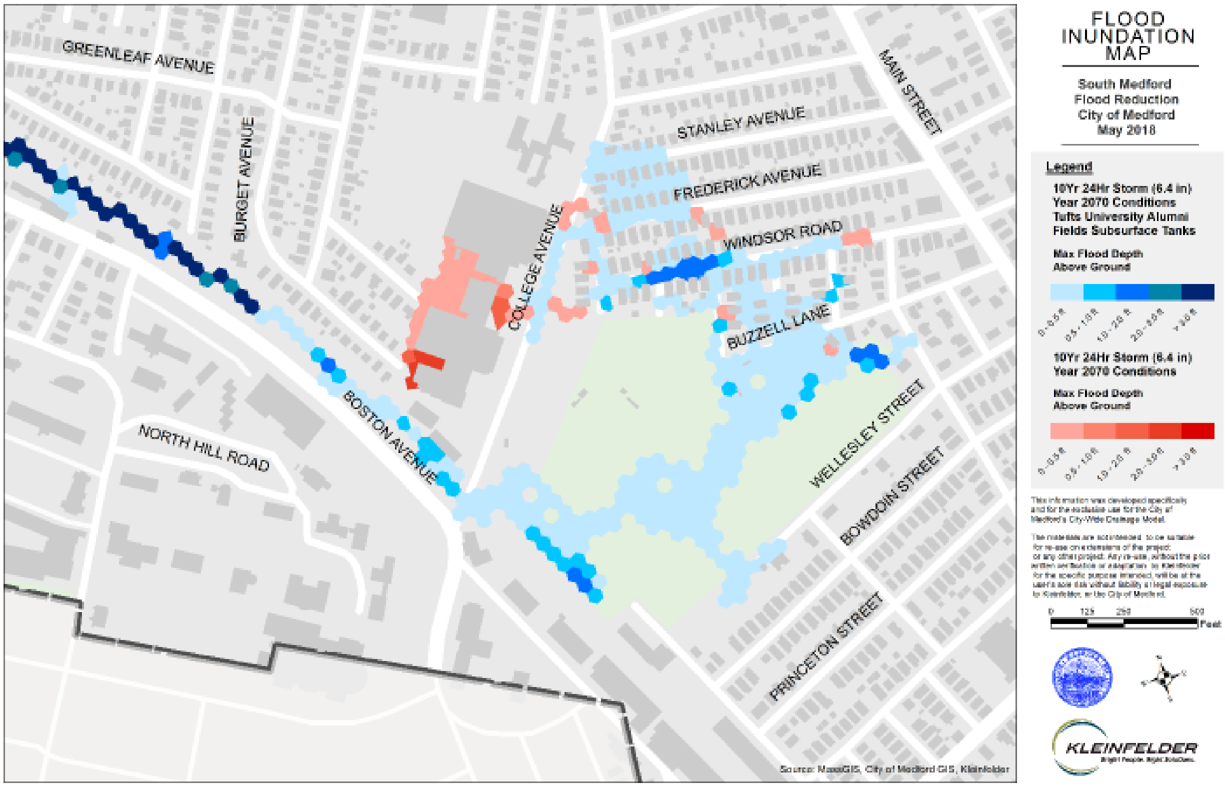


Figure 16 – Flood reduction benefits (red = areas that no longer flood) from Tufts University Alumni Fields stormwater improvements

4. Flood mitigation strategies

The following sections summarize various potential flood mitigation strategies at neighborhood and site-specific scales that were evaluated for South Medford. Strategies include conceptual-level analyses on:

1. Neighborhood-wide impervious area reduction (overall and targeted reduction)
2. Updated stormwater policies for new development at neighborhood scale
3. Neighborhood-wide and site-specific green infrastructure
4. Site-specific gray and green infrastructure

4.1. Neighborhood-wide strategies

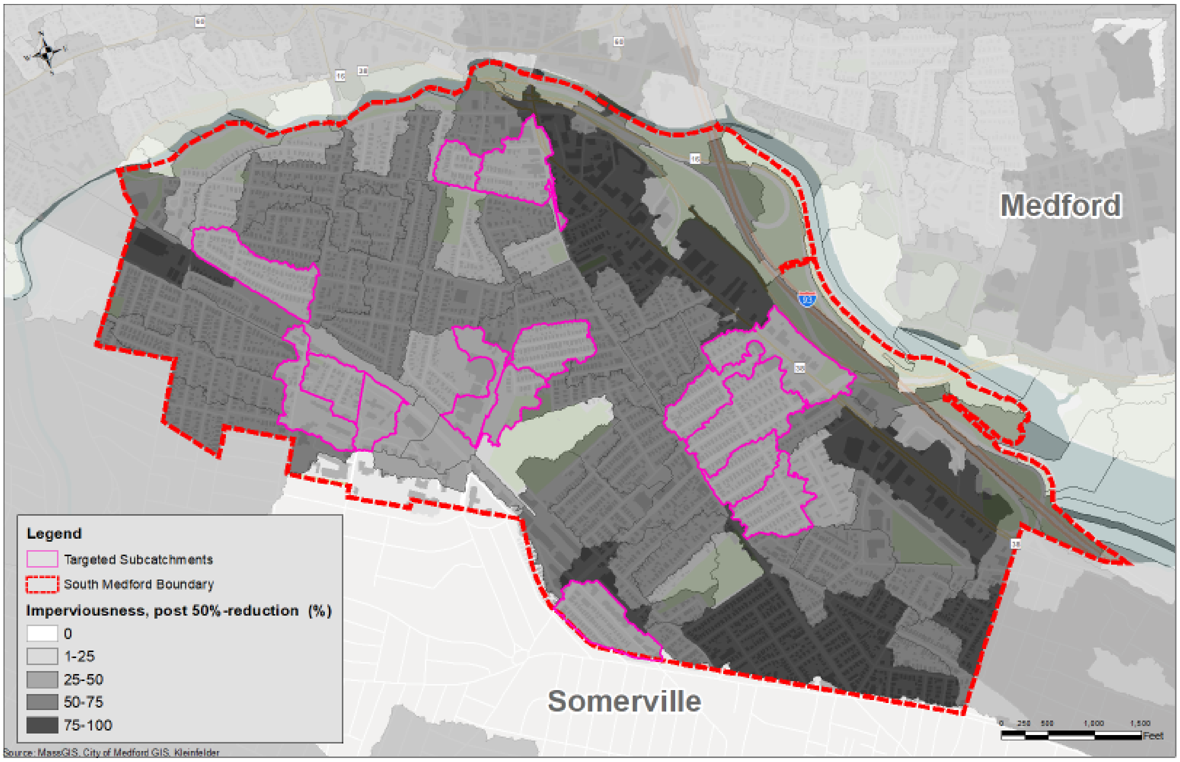
The efficacy of stormwater management strategies, such as reduction of impervious area and consideration of more stringent stormwater policy related to on-site stormwater capture for new development, were tested at a neighborhood-wide scale in terms of flood reduction benefits using the updated South Medford model. These strategies were tested using the 10-year 24-hour design storm by 2070. This storm scenario was selected as a reasonable evaluation scenario upon discussions with the City for the following reasons:

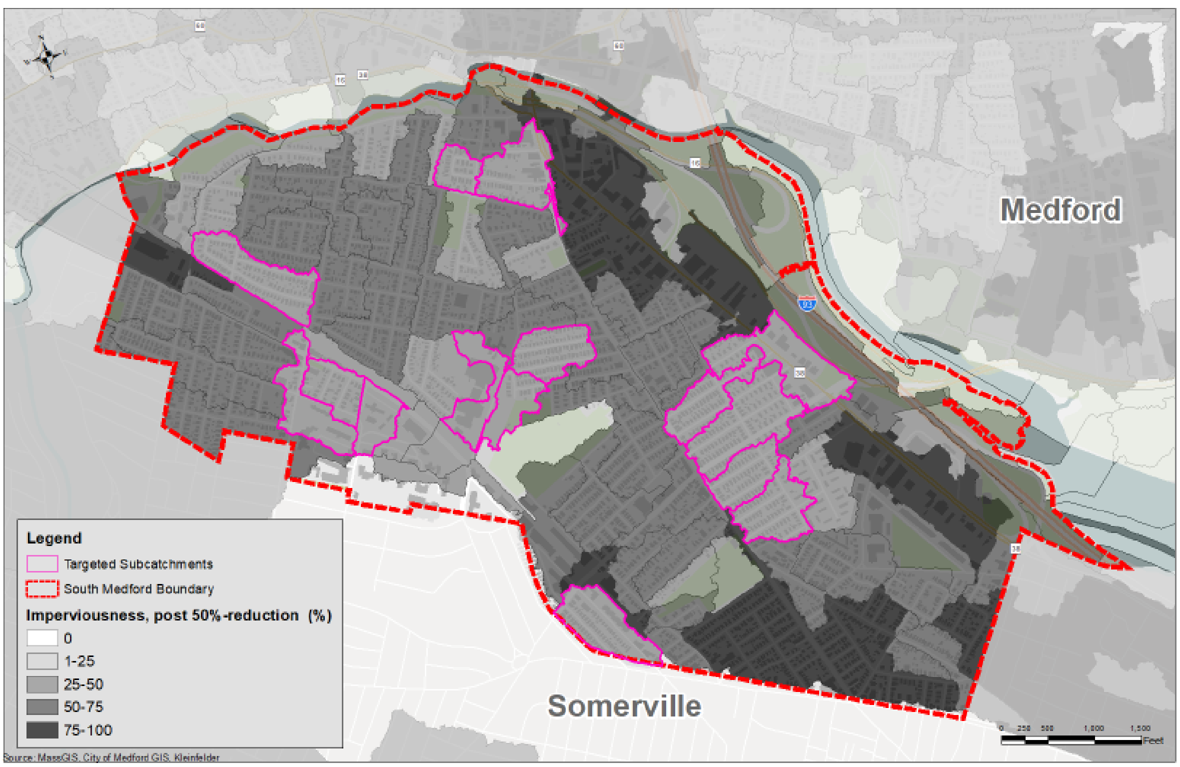
- The projected 10-year 24-hour storm by 2070 is very similar to the present 25-year 24-hour storm in terms of rainfall depth and peak intensity. Since the 10-year event is a relatively frequent event, it is important that recommended flood reduction strategies are evaluated for this type of frequent event in the future.
- Flood reduction projects or policies that get designed and implemented today or in the near-future are likely to be within their useful life and still in place by 2070. Therefore, it is important that these projects and policies are evaluated for their future efficacy considering this scenario.

4.1.1. Neighborhood-wide impervious area reduction

Impervious area reduction was modeled at the catchment scale as a neighborhood-wide strategy for flood reduction. Three different types of impervious area reduction scenarios were modeled and tested using the 10-year, 24-hour storm for 2070 climate conditions:

- Overall 50% reduction of impervious area for *all* catchments in South Medford
- 50% reduction of impervious area for catchments in South Medford that are
    - i. more than 50% impervious, and
    - ii. more than 75% impervious
- 50% and 75% reduction of impervious area in targeted catchments upstream of flood-prone areas in South Medford (**Error! Reference source not found.**)


Medford
Somerville
Legend
Targeted Subcatchments
South Medford Boundary
Imperviousness, post 50%-reduction (%)
0
1-25
25-50
50-75
75-100
Feet
Source: MassGIS, City of Medford GIS, Kleinfelder


Medford
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Targeted Subcatchments
South Medford Boundary
Imperviousness, post 50%-reduction (%)
0
1-25
25-50
50-75
75-100
Feet
Source: MassGIS, City of Medford GIS, Kleinfelder

Figure 17 – Impervious area by catchment under existing conditions (top); and
50% reduction of imperviousness of targeted catchments upstream of flood-prone areas Scenario (bottom)

Table 2 summarizes the flood results and statistics for each of the above four scenarios and under the no-action scenario for the 10-year 24-hour by 2070. The effectiveness of the impervious area reduction strategies was evaluated based on the metric how many acres of impervious area (IA) needs to be reduced (in acres) to achieve 1 million gallon (MG) of reduction in flood volume, expressed as acres/MG, with the goal of minimizing this ratio.

Table 2 – Summary of flood statistics for neighborhood-wide alternative 1

Parameters	10-year, 2070 (No action)	Neighborhood-wide Alternative 1 - Impervious Area (IA) Reduction				
		Overall Reduction of IA by 50%	50% IA Reduction by Threshold of %IA		%IA Reduction in Catchments Upstream of Flood-Prone Areas	
			50% Impervious Area Reduction for Catchments >50% Impervious	50% Impervious Area Reduction for Catchments >75% Impervious	50%	75%
Flood Volume (MG)	15.6	12.4	13.0	14.7	14.6	13.8
Total IA Reduced (ac)	N/A	285.1	247.5	83.7	49.6	74.4
IA Reduced/ Flood Volume Reduced (ac/MG)	N/A	89.1	94.0	97.3	**47.9**	**41.0**
% Area flooded	9%	6%	6%	8%	8%	7%
% Properties flooded	20%	15%	15%	19%	19%	18%

While an overall 50% reduction of impervious area produced the largest reduction in flood volume (3.2 MG), the impervious area reduction necessary was also the largest of any scenario (285.1 acres). This results in a ratio of 89.1 acres of impervious area reduction necessary to achieve 1 MG of flood reduction. A threshold approach by reducing the impervious area for catchments that are most impervious, produced slightly higher ratios of impervious area reduction in acres required to achieve 1 MG of flood volume reduction at 94.0 and 97.3 for thresholds of 50% and 75%, respectively. For these thresholds, while the impervious area reduction is lower compared to the overall impervious area reduction scenario, the total flood reduction volumes were also lower (2.6 MG and 0.9 MG for the thresholds of 50% and 75%, respectively). This indicates that an arbitrary threshold approach of impervious area reduction in catchments is not as efficient.

A targeted approach, that focuses on impervious area reduction in catchments directly upstream of surcharged drain pipes and flooded areas, required the least amount of impervious area reduction in acres to reduce the flood volume by 1 MG at 47.9 and 41.0 for 50% and 75% reductions, respectively. While these scenarios did not achieve the same amount of flood reduction volumes (1.0 MG and 1.8 MG for 50% and 75% targeted reductions, respectively) compared to the overall impervious area reduction scenario (3.2 MG), the benefits are maximized to achieve 1 MG of flood reduction by reducing the least amount of impervious area. Figure 18 illustrates the targeted catchments upstream of the flood prone areas where impervious area was reduced by 50% and Figure 18 displays the expected flood reduction benefits for this scenario (shown in depths of blue) compared to the no-action scenario (shown in depths of red) for the 10-year 24-hour storm by 2070. Flood reduction benefits are visible in the areas downstream of the targeted catchments (areas circled in green in Figure 18).

Figure 18 – Flood reduction benefits from 50% impervious area reduction in targeted catchments upstream of flood prone areas (areas circled in green correspond to locations where flooding is reduced)

4.1.2. Updated Stormwater Policies for New Development at Neighborhood Scale

The current stormwater policy effective for new development in the City of Medford requires that the post-construction peak discharge rate to be equal or lower than the pre-construction peak discharge rate using present day design storms. With the upcoming redevelopment opportunities, shown in Figure 19 below, the City wants to explore the effectiveness of a more stringent stormwater policy in terms of flood volume reduction.

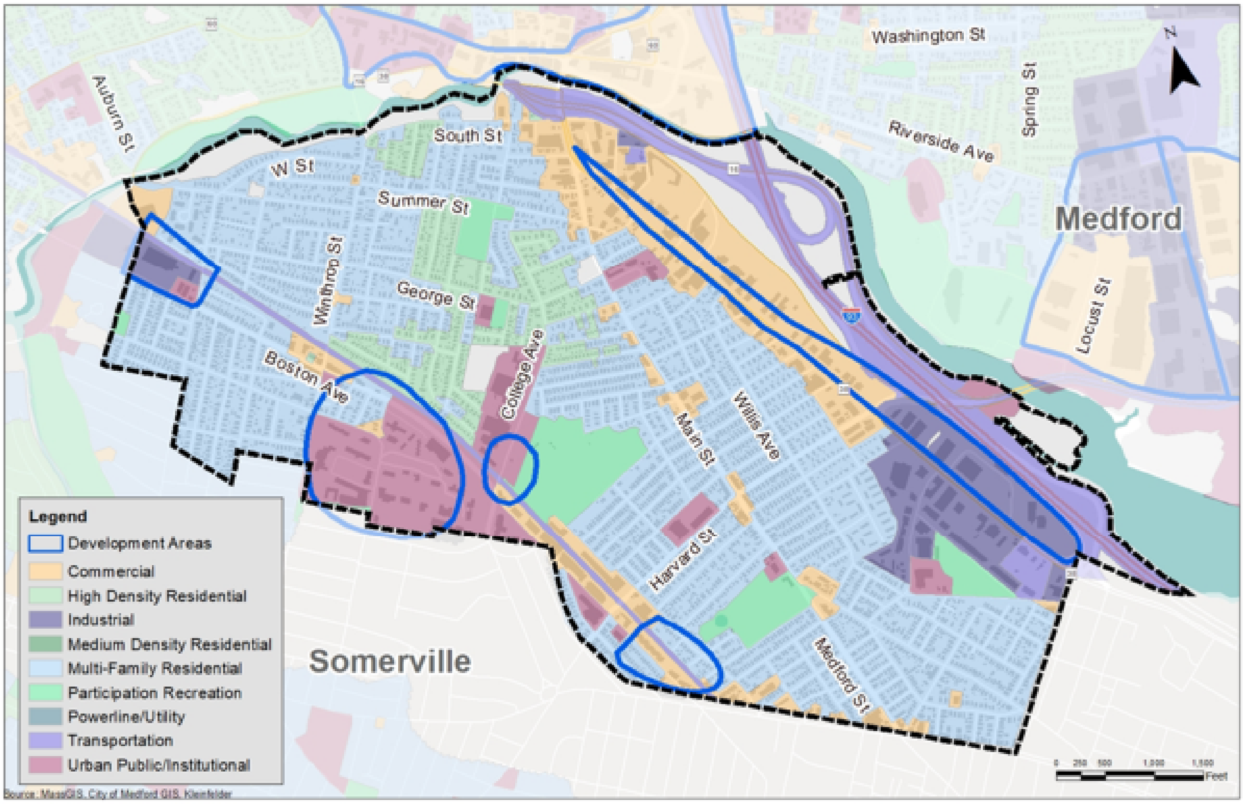

Figure 19 – Flood reduction benefits from 50% impervious area reduction in targeted catchments upstream

The two potential stormwater management policies are as follow:

1. Post-construction peak discharge rate from a 2070 10-year 24-hour storm (6.4-inch total precipitation) will need to be equal to or lower than that of the pre-construction peak discharge rate from a Present-day 10-year 24-hour storm (4.9-inch total precipitation)
2. Post-construction peak discharge rate from a 2070 10-year 24-hour storm (6.4-inch total precipitation) will need to be equal to or lower than that of the pre-construction peak discharge rate from a 2070 2-year 24-hour storm (3.7-inch total precipitation)

Figure 20 displays storm hydrographs for an example model catchment and shows the minimum storage volumes necessary to meet peak discharge reduction requirements for each stormwater policy. The second option is more aggressive in terms of the stormwater runoff volume that needs to be captured in order to satisfy the requirement.

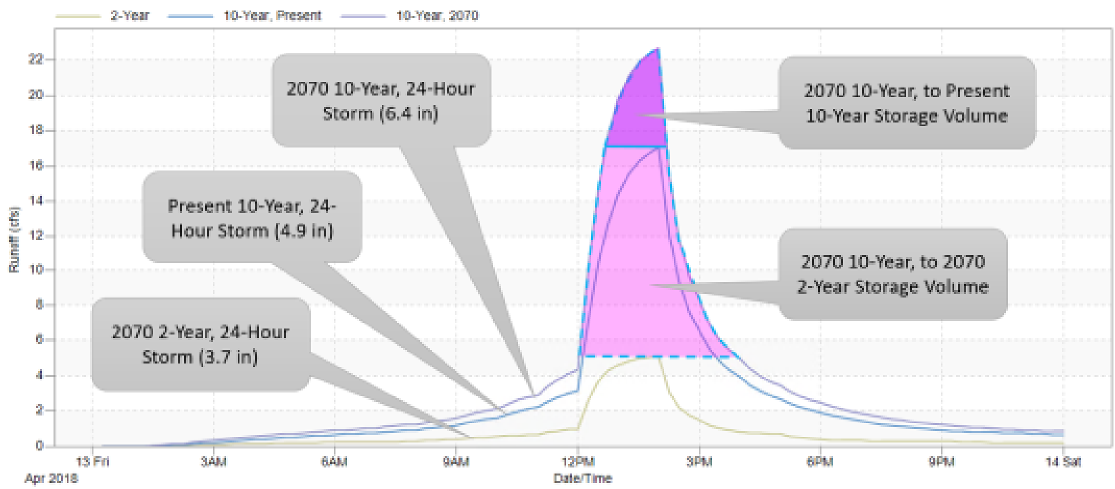

Figure 20 – Example of a stormwater hydrograph for a model catchment. Displaying required storage volumes for stormwater policies

A model scenario was simulated based on the second option. Areas of potential future development were identified based on areas of proposed development as referenced from the 2013 City of Medford Hazard Mitigation Plan Update[8] and these parcels were modeled such that the peak discharge from the 10-year 24-hour storm by 2070 from these areas did not exceed the peak discharge for the 2-year 24-hour storm by 2070. Figure 21 shows the expected flood reduction benefits (areas circled in green) considering implementation of the more stringent stormwater policy (flood depths shown in blue) compared to the no-action scenario (flood depths shown in red) for the 10-year 24-hour storm by 2070.

[8] http://www.medfordma.org/storage/2013/06/Medford_DRAFT_06-12-13.pdf

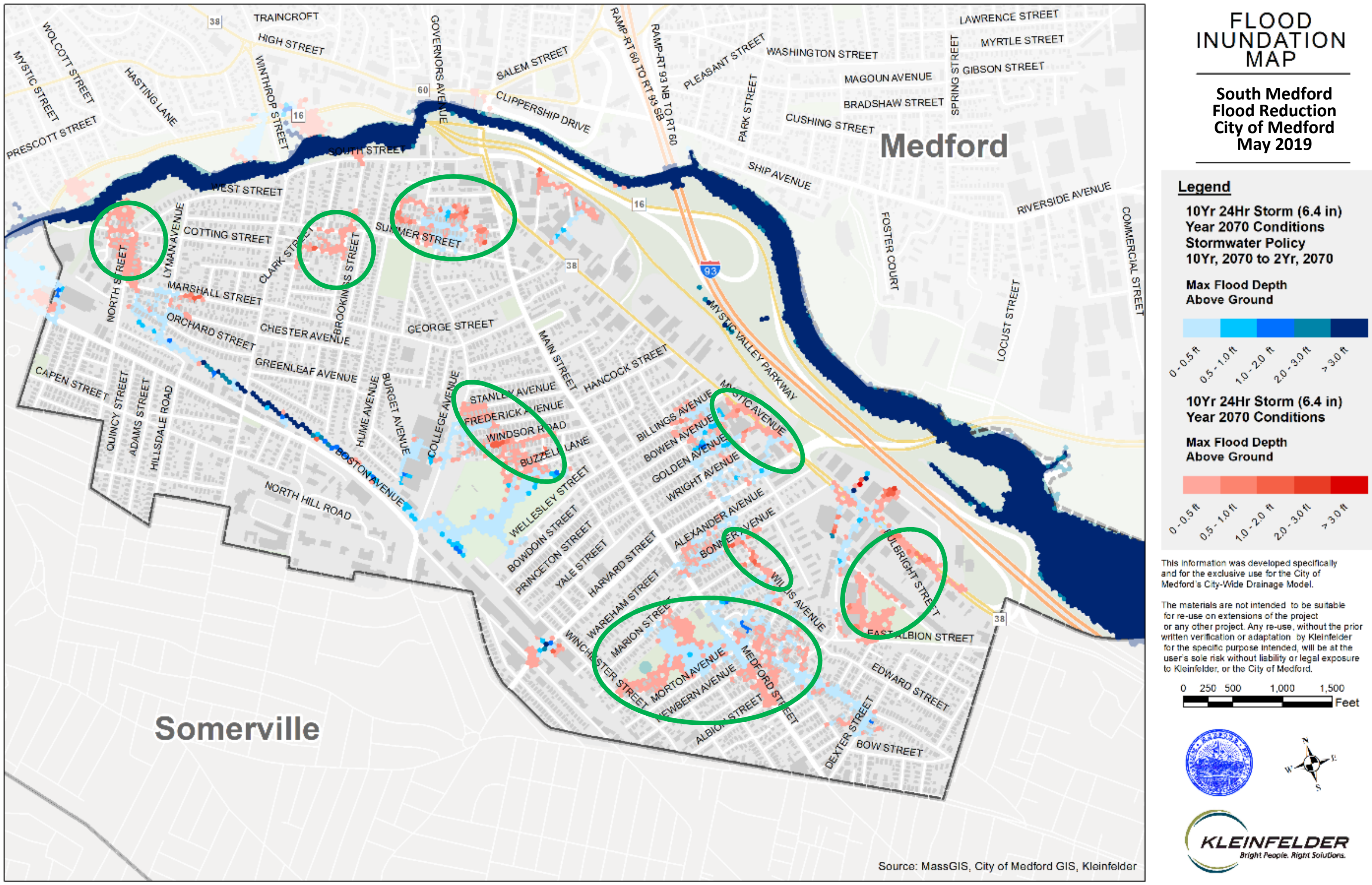

Figure 21 - Flood reduction benefits from stormwater policy of post-development peak discharge reduction from 2070 10-year, 24-hour Storm to 2070 2-year, 24-hour storm (areas circled in green correspond to locations where flooding is reduced)

Table 3 summarizes the flood statistics for both stormwater policies compared to the no-action scenario for the 10-year 24-hour storm by 2070. Assuming the existing drainage system to have the same conveyance capacity and the current stormwater policy to stay in place, flood volumes in South Medford for the 10-year, 24-hour storm are expected to increase from 12.2 MG in present day to 15.6 MG in 2070 caused by more frequent and intense rainstorms.

If the City adopts the stormwater policy option 1, the total flood volume is expected to remain the same as present at 12.2 MG, assuming that new development can capture the flood volume such that peak flow from the 10-year storm by 2070 (6.4-inch of rainfall) is no worse than the peak flow from the present 10-year storm (4.9-inch of rainfall).

The City can work with developers to receive additional flood reduction benefits with option 2. The additional flood volume captured on-site within the redeveloped parcels can reduce the total flood volume to 10.2 MG. Under this scenario, flooding is reduced for many areas of South Medford including the areas around Summer Street, Medford Street and Tufts Park, Bowen Avenue and Mystic Avenue, and Windsor Road and the Tufts Alumni Fields. The spatial distribution of potential development areas both upstream and downstream of flood prone areas and the proposed increased stringency of the stormwater storage requirements would result in significant flood volume reduction throughout the South Medford area.

Table 3 – Summary of flood statistics for neighborhood-wide alternative 2

Parameters	10-yr, 2070 (No action)	Neighborhood-wide Alternative 2 - Stormwater Policy for New Development Parcels	
		Post-construction, 10-yr 2070, pre-construction, 10-yr present	Post-construction, 10-yr, 2070, pre-construction, 2-yr, 2070
Flood Volume (MG)	15.6	12.2	10.2
% Area flooded	9%	6%	4%
% Properties flooded	20%	16%	11%

4.2. Neighborhood-wide and Site-Specific Green Infrastructure Implementation

Green infrastructure includes best management practices and/or engineering installations that mimic the natural environment. By restoring the natural ecosystem, green infrastructure can provide benefits, such as flood reduction, improve water quality, reduce urban heat island impacts and lower energy demands, and creating a more livable cityscape.

Green infrastructure strategies were considered for South Medford both at the neighborhood-wide or catchment-wide scale and at specific sites as described in the following sections.

4.2.1. Targeted catchment-wide implementation

In the neighborhood-wide impervious area reduction alternative (Alternative 1), a 50% reduction in impervious area in targeted catchments upstream of flood-prone areas was determined effective in terms of flood reduction. This reduction in impervious area can be conceptualized as removing existing paved surfaces and replacing with pervious surfaces that resemble naturally unpaved surfaces. While this scenario provided results to inform relative benefits by reducing imperviousness, in practical terms it can be challenging and almost impossible to achieve a 50% neighborhood-wide reduction of impervious area in a densely developed neighborhood such as South Medford.

Green infrastructure provides the means to work around this challenge by reducing the percent of directly-connected impervious area (DCIA) instead of percent of total impervious area (IA). DCIA includes all impervious areas that are directly connected to a waterbody or the drainage system. When green infrastructure is installed in a catchment, the IA that drains into or is tributary to that green infrastructure is no longer classified as DCIA. For example, if a portion of a roadway in a catchment drains to an infiltrating catch basin, the percent DCIA for that catchment will be reduced even though the percent of total IA for that catchment remains the same since that portion of the road still remains as paved.

This scenario evaluated the effectiveness of catchment-wide green infrastructure implementation in the targeted catchments upstream of flood prone areas that were identified as part of neighborhood-wide Alternative 1. Five green infrastructure strategies were evaluated as part of this scenario: bioretention basin, porous pavement, green roof, infiltration trench, and rain barrels.

Green infrastructure strategies were sized to capture runoff from the first inch of rainfall for 50% of the impervious area per targeted catchment. This level of implementation reduces the DCIA for target catchments by 50% for precipitation events with equal or less than 1 inch of total rainfall. The distribution of green infrastructure strategies for each targeted catchment was determined based on land use type as certain strategies are more suitable for certain land use types.

Table 5 shows the green infrastructure strategies identified for each land use type and

Table ***5*** summarizes the level of implementation by type distribution of green infrastructure strategies and their respective footprint (as square foot) for each targeted catchment.

Table 4 – Green infrastructure strategies identified for different land use types

Land Use	Bioretention Basin	Porous Paving	Green Roof	Infiltration Trench	Rain Barrel
Commercial			✓	✓	
High Density Residential	✓		✓	✓	
Industrial	✓		✓		
Multi-Family Residential	✓	✓			✓
Open Land	✓				
Participation Recreation	✓				
Transportation	✓	✓			
Urban Public/Institutional			✓	✓	

Table 5 - Level of implementation and distribution of green infrastructure strategies for targeted catchments

Catchment Name	Bioretention Basin Footprint Area (sf)	Porous Paving Footprint Area (sf)	Green roof Footprint Area (sf)	Infiltration Trench Footprint Area (sf)	55-gallon rain barrels needed to treat water quality volume
S385	2217	7292	0	0	231
S392	5369	17656	3149	309	560
S393	2254	7414	73333	7205	235
S442	1315	4261	29790	2915	133
S456	21	47	27077	2658	1
S461_1	121	398	21184	2081	13
S461_2	2090	6874	8690	854	218
S463	4002	11647	9779	789	369
S477	3739	3443	128088	12079	105
S479	2361	4190	10010	983	133
S486	4347	14296	4259	418	453
S507	6438	21172	29609	2909	671
S524	3546	11661	2668	262	370
S533	4881	16052	2	0	509
S557	3639	12758	50742	4985	353

Based on model results, the catchment-wide green infrastructure implemented yielded a flood reduction of 0.4 MG. The relatively small flood volume reduction can be explained based on a combination of the following reasons:

1) Green infrastructure is more effective in capturing the first 1” – 1.5” of stormwater runoff, but less effective in reducing maximum flood volume when the precipitation is at peak

intensity. The benefits of green infrastructure will be more prominent under smaller rainstorms than the 24-hour duration design storms being considered in this study.

2) Physical soil conditions in South Medford are not ideal for infiltration. The soils in the area are mostly clay or silt that have very low infiltration rates when thoroughly wetted.
3) A conservative implementation level of green infrastructure was considered in this scenario – only implemented in 15 of the 94 catchments in South Medford.

It is important to acknowledge the co-benefits of green infrastructure, such as reducing urban heat island effect, improving local water quality and beautifying cityscape. These co-benefits have not been quantified in this study. Additionally, green infrastructure can be an effective tool when combined with site-specific solutions, where green infrastructure can help to decrease stormwater runoffs prior to discharging into the drainage system, as summarized in following sections.

4.2.2. Site-specific Open Space Implementation

In addition to catchment-wide green infrastructure implementation, site-specific implementation of subsurface infiltration tanks was evaluated at two public open space locations: Barry's Playground and Tufts Park. Public open space locations are well suited for the installation of large-scale subsurface infiltration tanks capable of detaining large volumes of stormwater flows.

Barry's Playground is a 3.5-acre public open space located along Summer Street in a multi-family residential neighborhood. The area directly downstream from the playground is expected to experience localized flooding under the 2070 10-year, 24-hour storm. For this scenario, a 240 ft x 250 ft x 5 ft subsurface infiltration tank, (2.24 MG of storage) with two inflow weirs from existing 12" and 18" storm drains, was modeled at Barry Playground.

Tufts Park is an 8.4-acre public open space along Medford Street in a multi-family residential neighborhood. The area downstream of the park, including sections of Medford Street and Main Street, is expected to experience nuisance flooding under the 2070 10-year, 24-hour storm. Additionally, the low-lying area around the Harvard Street underpass and the park area itself are expected to experience more severe flooding of up to 1-3 feet under the same 2070 10-year, 24-hour storm. For this scenario, a 200 ft x 300 ft x 5 ft subsurface infiltration tank (2.24 MG of storage) with one inflow weir from an existing 42" storm drain was modeled at Tufts Parks. Figure 22 below shows a site overview plan for the subsurface infiltration tanks modeled at Barry Playground and Tufts Park. Figure 23 shows the expected flood reduction benefits (areas circled in green) from catchment-wide and site-specific green infrastructure (flood depths shown in blue) compared to the no-action scenario (flood depths shown in red) for the 10-year 24-hour storm by 2070.

Figure 22 –Barry's Playground infiltration tank (top); Tufts Park infiltration tank (bottom)

Figure 23 - Flood reduction benefits from catchment-wide and site-specific green infrastructure implementation

Table 6 summarizes the flood statistics for the modeled scenario including both catchment-wide and site-specific green infrastructure implementation. Catchment-wide implementation of green infrastructure is expected to provide minimal flood volume reduction benefits (0.4 MG). Catchment-wide green infrastructure strategies were designed to capture stormwater flows from the first inch of rainfall which provides little flood reduction benefit at the peak of the storm. Combined with the site-specific implementation, the flood volume reduction benefits are expected to improve to 1.4 MG. While flooding is expected to reduce in the areas around College Avenue and Tufts Park, there are minimal improvements to the flooding in the Bowen Avenue, Mystic Avenue and Summer Street areas.

Table 6 - Summary of flood statistics for catchment-wide and site-specific green infrastructure scenario

Parameters	10-yr 2070 (No action)	Green Infrastructure	
		Catchment-wide Implementation for Upstream Targeted Catchments	Catchment-wide Implementation for Upstream Targeted Catchments + Site-specific Implementation
Flood Volume (MG)	15.6	15.2	14.2
% Area flooded	9%	8%	8%
% Properties flooded	20%	20%	19%

4.3. Green + Gray Infrastructure Implementation

4.3.1. Site-specific Gray Infrastructure Implementation

Gray infrastructure in this report is defined as traditional engineering systems that generally use concrete, solid plastics, or steel, implemented to manage impacts from natural hazards such as flooding. Gray infrastructure strategies for drainage systems to manage stormwater can include strategies that mitigate flooding by either detaining water, such as large storage tanks and/or by draining floodwaters away from flooded areas as quickly as possible, such as larger pipes and pump stations. Three site-specific gray infrastructure strategies were evaluated, in aggregate with the green infrastructure strategies as measures to reduce flood impacts for the 10-year, 24-hour storm, under 2070 climate conditions.

The area around Bowen experiences flooding under current conditions which is expected to worsen with climate change conditions. Catchment-wide and site-specific implementation of green infrastructure are expected to have minimal flood reduction benefits to the area. The modeled gray infrastructure scenario includes proposed reversal and re-routing of stormwater flows from Bowen Ave to Mystic Ave and upsizing of existing stormwater pipes on Willis Avenue and Mystic Avenue to 3 feet in diameter.

The second site-specific gray infrastructure strategy included in this scenario involves upsizing of existing stormwater pipes on Thomas Street and Main Street to 3 feet in diameter. Thomas Street and Emerson Street experience flooding under current conditions which is expected to worsen with climate change conditions.

The Harvard Street underpass is a low-lying area that travels underneath the MBTA railroad tracks. This area is expected to experience significant flooding with minimal mitigation from green infrastructure implementation strategies. This model scenario proposes reversal and re-routing of stormwater flows to Boston Avenue and abandonment of the storm drain connection on Harvard Street. Figure 24 and Figure 25 display the three site-specific gray infrastructure strategies. Figure 26 shows the expected flood reduction benefits from this modeled scenario.

Figure 24 – Bowen Avenue proposed gray infrastructure improvements

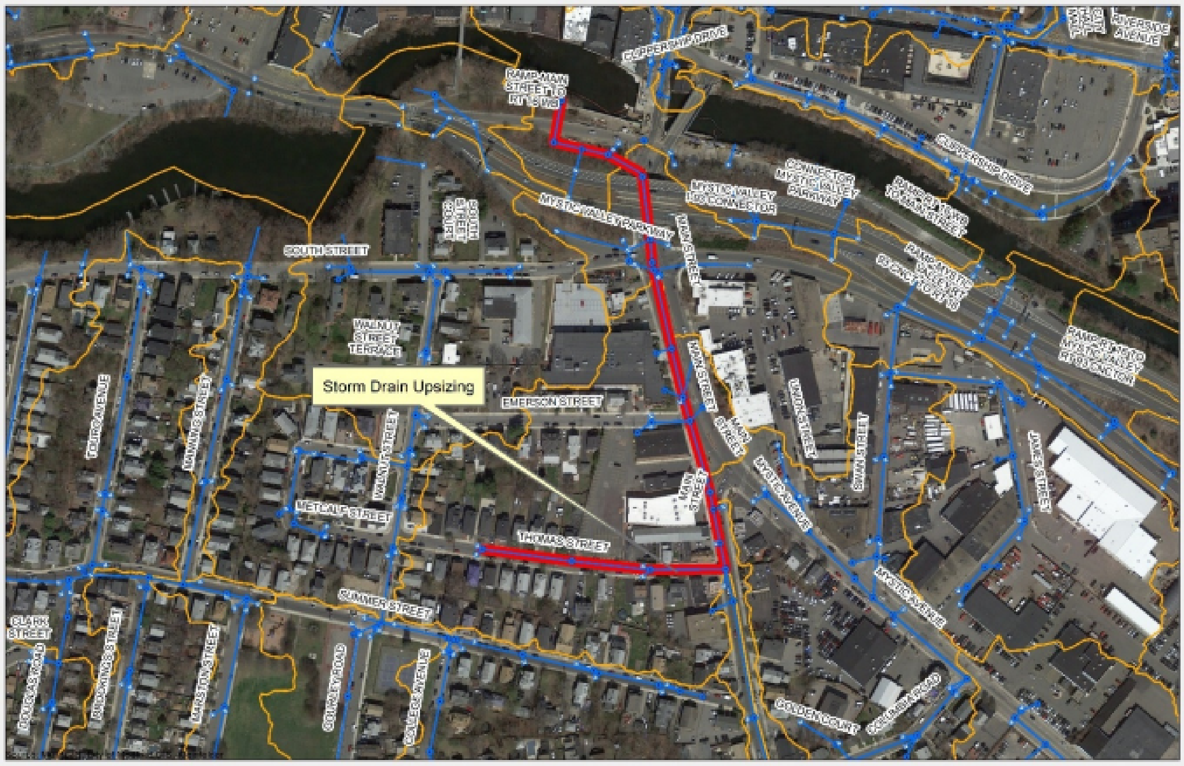

Figure 25 – Thomas Street and Main Street proposed gray infrastructure improvements (top); Harvard Street proposed gray infrastructure improvements (bottom)

Figure 26 - Flood reduction benefits from green and gray infrastructure implementation

Table 7 summarizes the flood statistics for the modeled scenario including green and gray infrastructure implementation. This scenario is expected to produce an additional 0.9 MG of flood volume reduction compared to the green infrastructure scenario for a total flood volume reduction of 2.3 MG. The addition of the gray infrastructure strategies is expected to significantly reduce flooding in the areas around Summer Street, Bowen Avenue and Mystic Avenue. At the Harvard Street underpass, the flows are rerouted, but downstream restrictions – small drainage pipes near the Tufts Park prevent the rerouted flows to be carried away quickly, the flood impacts at the underpass will not see improvements until the downstream restrictions are removed.

Table 7 - Summary of flood statistics for green and gray infrastructure scenarios

Parameters	10-yr 2070 (No action)	Green Infrastructure		Green + Gray Infrastructure
		Catchment-wide Implementation for Upstream Targeted Catchments	Catchment-wide Implementation for Upstream Targeted Catchments + Site-specific Implementation	Catchment-wide Green Infrastructure Implementation for Upstream Targeted Catchments + Green and Gray Site-specific Implementation
Flood Volume (MG)	15.6	15.2	14.2	13.3
% Area flooded	9%	8%	8%	8%
% Properties flooded	20%	20%	19%	19%

5. Summary of results

Figure 27 compares the flood volume for all modeled reduction scenarios for the 10-year, 24-hour storm by 2070. The stormwater policy scenario is expected to achieve the largest reduction in flood volume (5.4 MG) of any modeled scenario. The demonstrated effectiveness of this strategy can be used inform the City's stormwater policies in the future. It should be noted that this is a stringent policy that could deter developers from developing parcels in Medford due to the additional costs associated with stormwater storage. Impervious area reduction scenarios are expected to provide varying levels of flood volume reduction from 1.0 – 3.2 MG. These scenarios can be difficult to implement in highly developed urban areas like South Medford but provide a simple approximation of the flood reduction benefits that can be expected from green and gray infrastructure strategies that capture a certain amount of stormwater flows from impervious surfaces. Implementation of catchment-wide and site-specific green infrastructure is expected to provide 1.0 MG of flood volume reduction. When combined with gray infrastructure an additional 1.3 MG of flood volume reduction is expected for a total of 2.3 MG. Results from this planning level study can be used to inform further analysis of the feasibility and constructability of modeled scenarios.

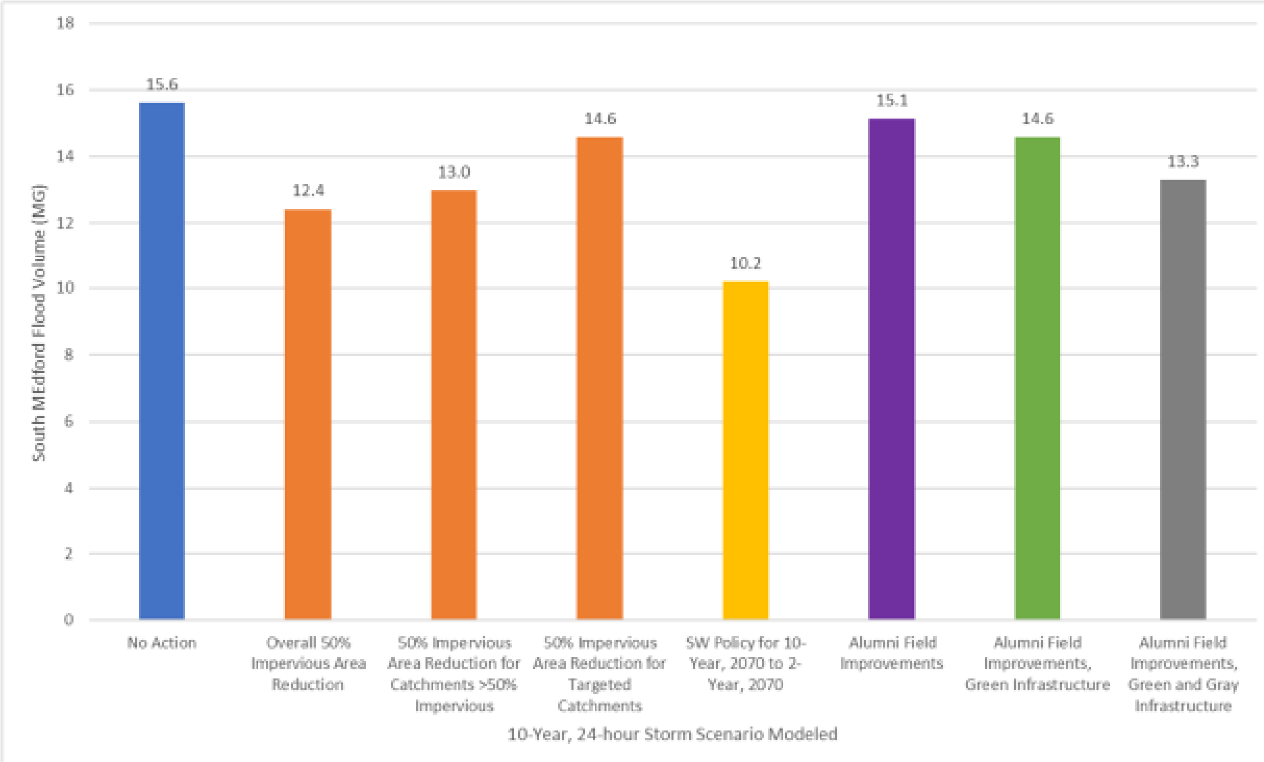

Figure 27 – Flood volumes for the 10-year, 24-hour storm by 2070 for all modeled scenarios

5.1. Next Steps

Model results show that chronic flood problem at the Harvard Street underpass is associated with drainage conveyance issues near the Tufts Park. The flood issues in the area between the underpass and the Tufts Park are mainly caused by 1) low-lying terrain, and 2) restrictive downstream capacity near the Tufts Park. Downstream of the Tufts Park, flood problems are exacerbated when the stormwater flows converge from North and South of Main Street, as well as the upstream flows from Harvard Street.

Similar flood problems were identified on Summer Street near Barry Playground under a future storm scenario with higher rain intensities. Conceptual modeled solutions to mitigate these flood impacts included impervious area reduction; implementation of new stormwater management design policies and guidelines; green infrastructure implementation; and, combined grey and green parcel site-specific implementation. Model results show that the grey and green site-specific solutions can be an effective solution to mitigate flood impacts with an appropriate design to manage stormwater flows.

5.2. Feasibility studies

The open space available at the Tufts Park and Barry Playground serve as two strategic candidates to conduct site-specific feasibility studies. The studies will undertake site-specific feasibility analyses for installation of a sub-surface infiltration "stormceptor" type tank system at the two locations, as well as evaluation and conceptual design of opportunistic surface enhancements and green infrastructure elements. Analyses can also include soil characterization, geotechnical soil testing, groundwater mounding analysis, stormwater storage tank sizing, and other physical and topological constraints.

5.3. West Medford, Town of Winchester and Winchester Reservoir

The City should also continue its effort to coordinate with neighboring towns within the Mystic River Watershed. West Medford is particularly prone to flash floods due to untimely flow release from the Winchester Reservoirs. The Winchester Reservoirs, owned and managed by the Town of Winchester, is situated within the Middlesex Fells Reservation that is directly upstream of the West Medford area. Previous records show that the drainage system in West Medford does not have the capacity to handle the combined flows from stormwater runoff in addition to the released flows from the reservoirs.